Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 7 (2011) 188–193

Procedia
Environmental Sciences

Application of spatial analysis to the examination of dengue fever in Guayaquil, Ecuador

Katty C. Castillo[a,*], Birthe Körbl[a], Anna Stewart[b], Javier F. Gonzalez[c], Facundo Ponce[c]

[a] German Diabetes Center, Institute of Biometrics and Epidemiology, Auf'm Hennekamp 65, 40225 Düsseldorf, Germany
[b]University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210, USA
[c] Heinrich-Heine University of Düsseldorf, Institute of Geography, Universitätstraße 1, 40225 Düsseldorf, Germany

Abstract

Dengue is the main viral disease transmitted by arthropods worldwide with over 50 million people infected yearly, especially in tropical and subtropical regions. In Ecuador epidemics of dengue erupted since 2000 with the appearance of the hemorrhagic form. However, studies in urban areas to better understand the spatial distribution of the disease are lacking. The objective of this study was to analyze the spatial distribution of reported cases of dengue fever in the city of Guayaquil (Ecuador) during the period from 2005 to 2009. Techniques of spatial statistics and GIS-Analysis are applied to characterize the geographical distribution of dengue incidence. Correlation analysis was used to determine hotspots of the distribution of the disease. This analysis revealed a significant spatial variation of disease incidence within the urban environment. Analysis of correlation indicated high spatial autocorrelation: Moran's I value was 0.37 ($p<0.001$). Preliminary results suggest a higher possibility of infection in places with already infected people. The results of this analysis suggest that dengue transmission in Guayaquil, Ecuador, is concentrated in local hotspots where strategies of prevention and control of the disease should be reinforced in order to avoid the spread of the epidemics to other areas of the city.

Selection and peer-review under responsibility of Spatial Statistics 2011

Keywords: Dengue; Hotspot; LISA.

* Corresponding author. Tel.: (+49) 0211-3382-273; fax: (+49) 0211-3382-677.
E-mail address: Katty.Castillo@ddz.uni-duesseldorf.de.

Selection and peer-review under responsibility of Spatial Statistics 2011
doi:10.1016/j.proenv.2011.07.033

1. Introduction

Dengue fever is the most important infectious disease transmitted to humans by arthropods [6]. Every year approximately 50 million people worldwide get infected [9]. Today no vaccine or specific therapy exists to treat the disease; therefore, disease control has focused on measures to control the mosquito vectors. Unfortunately, vector control has had limited effectiveness in preventing dengue fever transmission [3], [4]. Thus, an analysis of the registered dengue fever cases and an identification of risk patterns become necessary. With this information it is possible to develop strategies for prevention and an effective control of epidemics.

1.1. Objectives

This retrospective study intends to elucidate spatial distribution patterns of reported cases of dengue fever for the city of Guayaquil, Ecuador. Specifically, the present work seeks to address the following questions:

- Is there a spatial correlation of reported cases of dengue fever?
- If there are clusters of high occurrence of dengue fever, where are they located?

1.2. Study Area

Guayaquil is located between 79°50' – 79°59' W and 2°02' – 2°18' S on the southwestern region of the province of Guayas, Ecuador. The city has a total area of 1800 km^2 and an estimated population for 2001 of around two million inhabitants.

Guayaquil has a tropical humid climate with a mean annual temperature of 26 ^{o}C and a mean precipitation of 1030 mm. The rainy season lasts from January to May, coinciding with the period of highest incidence of dengue throughout the year.

Cases of dengue in the country are known to occur from the 1980s, but only documented in Guayaquil since 2005, with epidemics cases happening in 2000, 2005 and 2007. All four serotypes of dengue fever have been circulating in the city since 2000.

2. Methods

2.1. Secondary Data Sources

The epidemiologic data used for this analysis was collected by the Ministry of Health of Ecuador from 2005 to 2009 for the city of Guayaquil. The location of every case of dengue fever registered during this period was digitalized by the authors of this paper with the geographical information system (GIS) Arcgis 9.3.

Population values of Census zones, provided by the National Statistics and Censuses Institute from Ecuador (INEC) for 2001, served as the basic unit for the analysis. These were digitalized as polygons with the incidence factors as attributes. All data were stored and managed as a geographical database with Arcgis 9.3. In addition, the Software GEODA was used for the statistical processing and analysis of the data.

2.2. Cluster Analysis

Spatial autocorrelation can be detected through global or local measures. The Moran I-coefficient is used frequently as a global measure. This enables to test for the existence of clustering in the whole investigation area. Analogous local measures are called LISA (Local Indicator of Spatial Association) [1]. LISA metrics are employed to measure neighborhood relations for each region. This measure is widely used because spatial dependencies are often not equal in all regions (inhomogeneous), but rather locally distinct. There are frequently clusters of regions with above or below average values for a variable (spatial concentration) and nearby regions with equal or contrary orientations (positive and negative spatial autocorrelation).

The existence of spatial autocorrelation of dengue fever was analyzed with the Moran I-coefficient, by testing the null hypothesis that there is a homogenous distribution of dengue fever cases in the whole area of investigation.

The Moran indices were calculated in GEODA by means of a neighborhood-matrix W, applying the same approach as [5], [10]. In order to obtain W, the criterion of "common border" is used, in which research areas with a common border are considered neighbors.

The Moran´s significance was performed utilizing the Monte-Carlo permutation test, under the assumption that the registered cases of dengue fever are randomly distributed in the investigation area. The number of permutations was set to 999.

The LISA-coefficient was applied to identify and characterize clustering in the spatial distribution of the cases of dengue fever. The detected clusters are classified into four categories: high-high, low-low, high-low and low-high. These categories are analogous to the four quadrants of the Moran scatterplot (Figure 1).

Low-high (outliers)	High-high (hot spots)
Low-low (cold spots)	High-low (outliers)

Figure 1. Possible results of the estimation of coefficients LISA.

If a cluster is high-high, there is evidence for neighboring regions with a high number of dengue fever cases. Clusters which are classified as low-low show neighboring regions with a low number of dengue fever cases. Cluster which are called high-low or low-high are treated as outliers.

The statistical significance of the clusters is tested in similar way as that of the Moran I-coefficient. Finally, using the cluster-classification, a risk map was generated.

3. Results

In total, 4328 cases of dengue fever were registered for Guayaquil between 2005 and 2009, from which only 3974 cases were used in the spatial analysis because of the lack of exact localization (addresses) for the rest of the cases. These numbers are presented in Figure 2 through the Standardized Incidence Ratio (SIR), which provides a measure of the number of registered cases of dengue fever for the evaluation period in relation to the population living in each sector. For the spatial autocorrelation analysis, 371 census zones were delineated.

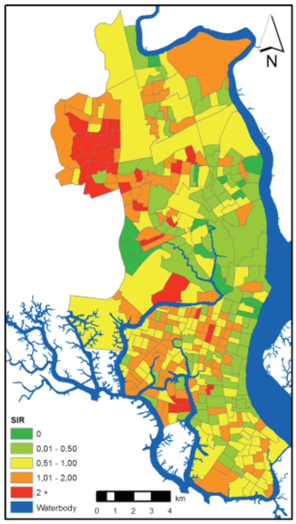

Figure 2. Standardized Incidence Ratio (SIR) calculated with population data from 2001 city census and dengue fever cases reported from 2005 to 2009.

Between 2005 and 2007 most of the cases occurred in the northwest of Guayaquil. The highest number of cases was registered in the year 2007, with high concentrations in the northwestern and southwestern regions of the city.

For the whole investigation period of 2005 to 2009 the Moran I coefficient takes the value of 0.37, which is higher than the expected value, suggesting that the cases of dengue fever show clustering over the whole investigation area.

135 number of census areas were classified as statistically significant clusters (p-Wert< 0.05) by means of the estimation of the LISA coefficient (Fig. 3). As hotspots (high-high) were classified 50 units. The northwest region, with 38, showed the most high-high spatial clustering, whereas the southwestern sector recorded only 12. In total 85 census areas were found as low risk zones (cold spots) for disease contagion. They were principally concentrated in the East part. For the rest of the city, no statistically significant clusters were identified.

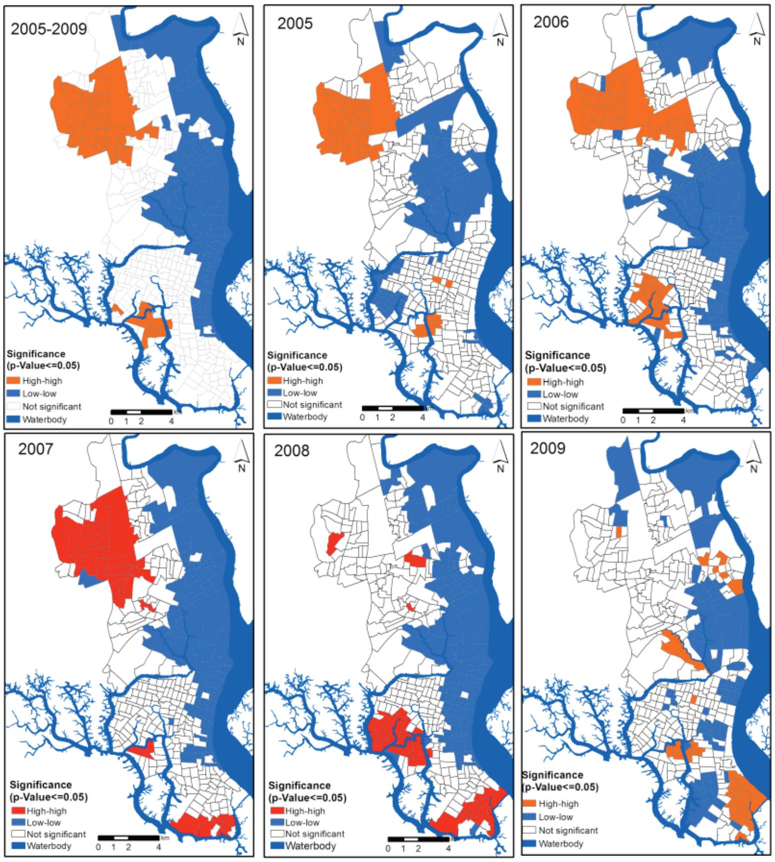

Figure 3. Results of the local cluster analysis in Guayaquil (Ecuador) with the LISA coefficient for the evaluation period of 2005 to 2009.

The evolution of the clusters over the investigation period can be observed in Figure 3. The map for the year 2005 shows an explicit pattern of clustering of dengue fever cases in the northwest and southwest regions, which extends in northeastern and south-central directions for 2006. In 2007 (an epidemic year) the northwestern cluster spread southwards. Additionally, new important concentrations of the disease appear into the southernmost region. In comparison to the previous years, 2008 and 2009 exhibited fewer cases. These showed up more intense in the southern regions and marginally in the northwestern regions.

4. Conclusion

Clusters of dengue cases were found by means of spatial statistics methods in some sectors of northern and southern Guayaquil, which are identified as hotspots (Fig. 2). Those city sectors are characterized by low socio-economical life standards (poor neighborhoods), with limited access to public utilities.

The results of this analysis indicate that from 2005-2007 hotspots of dengue fever incidence were located in low income neighborhoods with limited access to public utilities. Similar results were obtained by [7], who studied the spatial distribution of dengue cases in Brazil between 1994-2004 using the Moran´s I-coefficient, finding a strong positive relationship between dengue fever and low socio-economic factors. Similar spatial patterns were found by [2], [8].

Interestingly, this analysis also suggests that the dynamics of dengue fever transmission evolved during the study period, because from 2008-2009, clusters of disease transmission in northeast Guayaquil were found in both middle and low income areas.

An important result of the present work is the determination of city areas of high risk for the disease (hotspots), on which should be focused the implementation of prevention measures and the intervention of the National Health Service is imperatively needed.

Acknowledgements

This research was funded by grants to K. Castillo from the Alban Program. The Ministry of Health of Ecuador (Secretary from Guayaquil) provided the cases data from dengue fever. Cartography used in the study was given by the Municipality of Guayaquil. Population values of Census zones were provided by the National Statistics and Censuses Institute from Ecuador (INEC). Support for this research was provided by the Geography Institute, Heinrich Heine University.

References

[1] Anselin, L. (1995). Local indicators of spatial association – LISA. *Geographical Analysis*, **27**, 93-115.

[2] Caiaffa, W., de Mattos, M. C., Di Lozenzo, De Lima, A., Gesteira, S., Salles, M. and et al. (2005). The urban environment from the health perspective: the case of belo horizonte, minas gerais, brazil. *Cad. Saude Publica* **21** 958–967.

[3] Clark, G. and Rubio-Palis, Y. (2008). Mosquito vector control and biology in latin américa. *J. of the American Mosquito Control Association* **24** 571–582.

[4] Derouich, M., Boutayeb, A. and Twizell, E. (2003). A model of dengue fever. *BioMedical Engineering* **2** 1–10.

[5] Hu, W., Clements, A.,William, G. and Tong, S. (2010). Spatial analysis of notified dengue fever infections. *Epidemiol. Infect.* 1–10.

[6] Kuno, G. (1995). Review of the factors modulating dengue transmision. *Epidemiologic Review* **17** 321–335.

[7] Mondini, A. and Chiaravalloti, F. (2008). Spatial correlation of incidence of dengue with socioeconomic, demographic and environmental variables in a brazilian city. *Science of the total Environment* **393** 241–248.

[8] Reiter, P., Lathrop, S., Bunning M., Biggerstaff, B., Singer, D., Tiwari, T. and et al. (2003). Texas lifestyle limits transmission of dengue virus. *Emerging Infectious Diseases* **9** 86–89.

[9] Troyo, A., Calderón, O., Fuller, D., Solano, M., Avendaño, K., Dave, Ch. and et. al. (2008). Seasonal profiles of Aedes aegypti (Diptera: Culicidae) larval habitats in an urban area of Costa Rica with a history of mosquito control. *J. of medical entomology* **33** 76–88.

[10] Wen, T., Lin, N., Lin, C., King, C. and Su, M. (2006). Spatial mapping of temporal risk characteristics to improve environmental health risk identification: A case study of a dengue epidemic in taiwan. *Science of the Total Environment* **367** 631–640.